# EDITORIAL
# Inquiry-Based Science Education: Theory and praxis

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Inquiry as a process of constructing knowledge about the physical and biological world is an integral part of science and it has also been introduced in science education a long time ago. In fact, it was thought that students' engagement in a knowledge-pursuing process similar to the scientific one, would be beneficial for their learning. In the past, prominent pedagogues, like Dewey for instance (1997), argued for instructional approaches that are based on experiences and reflective thinking and trigger students' interest. These suggestions were linked to constructivist theories of learning (Bruner, 1961; Ausubel, Novak & Hanesian, 1978) and gave rise to a model of instruction that was called the "learning cycle" (Heiss, Obourn & Hoffman, 1950, in Bybee et al., 2006).

The "learning cycle" starts with the phase of "exploration" and gradually proceeds to the phases of "getting experience", "organizing learning" and "applying new knowledge". This model does not seem to take into account the possible contribution of peer interactions to individual learning. In fact, it was not until later that *social* constructivism (Vygotsky, 1978; Driver et al., 1994) influenced the notion of inquiry instruction. A large amount of research has been concerned with the effect of inquiry teaching in the form of "learning cycle" and suggests that this may be promising. In other words, inquiry teaching has been shown to result in better science learning and higher achievement, improved reasoning ability, and more positive attitudes towards science and science learning (Lawson, 1995; Lawson, Abraham & Renner, 1989).

Nevertheless, the suggested introduction of the so-called "scientific method" in science education has been criticized rather strongly. Students cannot actually "re-discover" scientific concepts by just applying the "scientific method". Scientists may do so, but they also invest significant time and effort and *do* have access to both empirical and theoretical resources that students don't. Scientific knowledge is thought to be constructed through the "hypothetical-deductive" "research wheel". Theories which are formulated in the inductive part of the "wheel" on the basis of scientists' epistemological commitments, conceptual lens and of course raw data, give rise to testable hypotheses which in turn trigger the "wheel's" deductive part (Johnson & Christensen, 2004). The arising question is how students can come up with theories if they previously have not been introduced to essential concepts through a content-focused teaching. It has been suggested that this problem might be solved with a careful choice of phenomena and empirical tests that would lead to pre-determined results. Nevertheless, something like that does not seem to be in line with *real* discovery and of course makes inquiry teaching look as dogmatic as content-centered one.

The focus of science education appeared to be shifting between the content knowledge and the process of scientific research as several educational reforms were taking place in USA and Europe (Millar & Driver, 1987). Nevertheless, the "content - process" dilemma may be false, since conceptual understanding seems to go in parallel with inquiry which gives rise to scientific reasoning. More reserved approaches to inquiry teaching would give emphasis on providing students with the target knowledge, as well as developing their practical skills and lab techniques. They might even suggest that knowing the outcome of the inquiry before doing it in class could be better for them. On the contrary, more authentic inquiry teaching would require students to design their own empirical tests for addressing their research questions and then *actively* come up with the target knowledge through their evidence-based conclusions. Despite the fact that inquiry practices may not be identical between school classrooms and real labs (Brown et al., 2006; Hume & Coll, 2008; Sadeh & Zion, 2009; Lin, Hong & Cheng, 2009), introducing students to the logic of scientific inquiry remains worth-trying and may follow them in their adult, everyday life.

Inquiry-based science education has been the topic of American educational projects (Abraham, 1997) and well-known publications like the "Atlas of Scientific Literacy" (AAAS, 2001, http://www.project2061.org/publications/atlas/). Educational policies about inquiry-based science curricula were also developed and introduced in many other countries (Minner et al., 2010), which keep investing on them. In U.K., such curricula have been closely linked to the contemporary need for scientific literacy (Millar & Osborne, 1998). Suggestions for the science education of the future draw heavily upon inquiry-based teaching and learning as shown in the "Rocard Report", an EC publication (Rocard et al., 2007). In fact, disseminating inquiry teaching from kindergarten to secondary school all over Europe has been the objective of recent European projects like "La main à la pâte", "Pollen", "Pathway" and "Fibonacci".

Teachers and students are required to act in inquiry teaching and learning environments with the assumption that these have been properly designed. Questions like "which may be the features of an authentic class inquiry" or "which may be the actions that teachers or students are expected to do in its context" are of great importance for both the learning outcome of instruction and the quality of relevant professional development courses that teachers attend. In fact, the designers of the aforementioned European projects attempted to address such questions and thus produced detailed tools for designing environments for inquiry teaching and learning and for monitoring teachers' and students' performance in their context. It seems however, that the main body of research so far concerns students and their post-achievement, whereas inquiry *teaching* remains more or less a "black box". The teaching practices, that are actually very important for how inquiry is implemented in real classes and how the IBSE model can be effectively introduced to the teachers, need to be highlighted much further.

This special issue aims at contributing to the discussion about IBSE as it presents four papers that shed light on theoretical and practical aspects of both inquiry teaching and learning. In the first paper, entitled "Inquiry-based learning in science and mathematics", Wynne Harlen, a member of the scientific committee of the "Fibonacci project", gives an overview of inquiry-based learning in science and mathematics nowadays. The paper starts with a brief summary of the rationale and history of the inquiry-based pedagogy and underlines that its importance for all students seems to be recognized by science institutions and policy makers. Going on with the meaning of inquiry in science and mathematics education, the author points out similarities and differences in these two contexts by focusing on aspects like the source of questions, the nature and function of investigation or the validation of solutions. Then Harlen shifts from theory to practice and addresses the issues of implementing as well as observing inquiry in real classes, and of gathering evidence to support its *actual* effectiveness. More specifically, the author discusses the issue of assessing the learning outcomes of this instructional model and suggests that *formative* assessment is necessary since it allows monitoring the progress of students' learning. Finally, she refers to the role of *summative* assessment, highlights the contradiction of using inquiry-based learning environments but uniform assessment tests that do not actually correspond to inquiry teaching and learning, and makes some interesting suggestions about it.

Monique Delclaux and Edith Saltiel are the authors of the second paper, entitled "Caractéristiques d'un enseignement des sciences fondé sur l'investigation et évaluation de dispositifs d'accompagnement des enseignants". The paper presents the experience gained from the "La main à la pâte" project, which started in 2000 with the aim of disseminating inquiry-based science education in primary schools in

France. More specifically, the authors are concerned with the observation of inquiry-based science sessions in 303 classrooms and relate the inquiry practices that have been monitored during the sessions with the type of support teachers were having by the local "pilot-centre" that was responsible for their professional development. Delclaux and Saltiel point out the need for having an observation tool and present the one that was developed in the context of the "La main à la pâte" project and used in their study. In fact, they focus on its main categories and the suggested teaching practices in each of them. Finally, the authors discuss features of the teaching approaches that were observed in many of their classrooms and link them to the innovative programs developed by the "pilot-centres" to support the renovation of the science-teaching methods.

Katarína Kotuľáková in her paper "Teachers Focusing on Pupils Prior Conceptions in Inquiry-Based Teaching" discusses teachers' practices with regard to identifying and using the existing ideas of pupils in the context of 30, inquiry-based science classes. The participants of the study were 13, in-service teachers of secondary education in Slovakia. Drawing upon the constructivist approach, Kotuľáková emphasizes the importance of students' prior knowledge in inquiry-based science education for both students' learning and teachers' instruction. The questions addressed have to do with how students' pre-conceptions are actually revealed by the teachers when students are in a process of formulating hypotheses and making predictions in the context of an inquiry class, as well as whether teachers handle the revealed pre-conceptions in ways that may actually lead students to meaningful learning. Classroom observations, students' recordings and teachers' interviews are the sources used by the author for obtaining her data. The findings indicate teachers' difficulties in eliciting students' prior knowledge as well as in reflecting on it in meaningful ways. The author makes suggestions for the improvement of the relevant teaching practices.

The last paper of the issue by Ergazaki and Zogza concerns biological inquiry in kindergarten. The aim of the authors is to shed light on the ways that kindergarten teachers and pupils may act in the context of inquiry-based didactic sequences for biological topics. To do this, they report on a series of case studies that were carried out in the context of the "Fibonacci" project in the area of Patras. The kindergarten classes that took part worked with didactic sequences of biology ("Life Cycle of Plants", "Growth Factors of Plants" and "Decomposition & Recycling") that were designed according to the IBSE principles, and observed with the "IBSE diagnostic tool" that has been developed in the context of the project. The findings concern teachers' practices for "building on the ideas of the children", "supporting children's investigations", "guiding children to conclusions" and "guiding children to share ideas", as well as the children's practices while "carrying out an investigation" and "keeping records". The authors identify several difficulties encountered by the teachers and their young students while engaged in inquiry-based teaching and learning of biology and discuss them thoroughly.

IBSE engages students in educational activities that may enhance their motives for learning science improve their conceptual understanding and give them the joy of discovering new things while interacting with their peers. The possible contribution of this instructional model in science education will probably remain an interesting topic of research in the following years and also inform the design of the professional development courses for teachers. This special issue of the "Re S M ICT E" journal focuses on the inquiry practices that are monitored in real classrooms and underlines the critical role of teachers in inquiry-instruction in kindergarten, primary and secondary education. The contributions attempt to highlight how complex may be to implement IBSE in real conditions and we hope that they can trigger fruitful thoughts for further discussion and research.

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